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16. ABSTRACT

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The sensitivity and accuracy of bioassays with four different microcosm communities were evaluated by comparing results with values reported for acute and chronic single species bioassays, other types of microcosms, and experimental ponds exposed to similar concentrations of atrazine. The ranges of sensitivity noted in these experiments were less than the range reported for single species bioassays using common test organisms and similar to those reported for other microcosms. The similarity between Leffler microcosm results and the responses reported for the experimental ponds suggests that the Leffler microcosms accurately reflected concentrations causing ecosystem level changes in the experimental ponds.

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The Effects of Atrazine on Microcosms Developed from Four Natural Plankton Communities

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Abstract. Comparisons were made among Leffler microcosms developed from four different natural communities and exposed to 0, 20, 100, 200, 500, 1,000, and 5,000 μg/L atrazine, a commonly used herbicide. Atrazine reduced net primary productivity, pH, and net productivity/respiration ratios in all four microcosm communities. In three of the four communities, the lowest observed ($P < 0.05$) effect concentration (LOEL) was 100 μg/L. In the fourth community the LOEL was 200 μg/L atrazine.

The sensitivity and accuracy of bioassays with four different microcosm communities were evaluated by comparing results with values reported for acute and chronic single species bioassays, other types of microcosms, and experimental ponds exposed to similar concentrations of atrazine. The ranges of sensitivity noted in these experiments were less than the range reported for single species bioassays using common test organisms and similar to those reported for other microcosms. The similarity between Leffler microcosm results and the responses reported for the experimental ponds suggests that the Leffler microcosms accurately reflected concentrations causing ecosystem level changes in the experimental ponds.

Microcosms have been used to assess the potential hazard of anthropogenic compounds to natural systems because microcosms have properties common to natural systems (Giddings 1981, 1983; Levin and Kimball 1984; National Academy of Sciences 1981; O'Neil and Waide 1982). One goal of microcosm research in the recent past has been to describe the benefits of microcosm bioassays in screening new chemicals for their potential hazard to aquatic environments. Generally, microcosms proposed for screening toxic chemicals are generic systems which do not replicate any specific natural system but simulate properties common to many ecosystems. Generic microcosms are of two types: 1. those derived from mixing stock monocultures (*e.g.*, the Standardized Aquatic Microcosm (SAM), Taub 1984), and 2. those derived from natural ecosystems (*e.g.*, Leffler microcosm, Leffler 1984; Giddings 1980).

The Leffler microcosm was selected for these experiments because it represents microcosms derived from natural communities and contains organisms representing several trophic levels. The Leffler microcosm has a well developed protocol which makes it a potential candidate for use in screening toxic chemicals. The protocol suggests examining only ecosystem level effects and ignores population dynamics. The test assumes that microcosms with differing species composition, but with similar broadly defined functional groups, will respond consistently at the ecosystem level. If this assumption is correct, microcosms derived from different natural ecosystems will also respond similarly to toxic stress.

The final goal of the Leffler bioassay, and that of many laboratory bioassays proposed for use in ecotoxicology, is to infer the types of response ex-

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pected from natural systems and to predict concentrations which will cause harm to natural ecosystems. The quality of inferences and predictions which can be made from these bioassays is a measure of their accuracy, and as such, accuracy is central to their use in hazard assessments. During the development of the Leffler protocol, and the protocol of other laboratory bioassays, precision and sensitivity have been the primary areas of evaluation because comparable information is usually not available for comparison with natural systems.

Because more information is needed to assess the sensitivity, precision, and accuracy of the Leffler protocol, the objectives of the study presented here were to:

a) describe the effects of atrazine on microcosms derived from natural communities,
b) determine whether the responses of microcosms developed from four different natural communities are consistent, and
c) determine the relative sensitivity and accuracy of these experiments by comparing results to those reported for single species bioassays, other types of microcosms, and experimental ponds exposed to similar concentrations of atrazine.

Materials and Methods

Microcosm Procedures

Microcosms used in these studies were prepared and operated according to the protocol developed by Leffler (1984). Since the protocol is lengthy, only a summary is presented here. Microcosms consisted of one-L beakers filled with 950 ml of Taub and Dollar (TD) media (1964) and 50 ml of a stock culture of organisms developed from a natural community. Each system was reinoculated with 50 ml of the same culture every week during the experiment to provide the same species pool to all microcosms during the experiment. The microcosms were allowed to stabilize for six weeks and then predominant organisms were identified to assure that major taxa required by the Leffler protocol were present. Each microcosm was then randomly assigned to a treatment or control group and atrazine was added (Day 0). No other atrazine additions were made during the remaining 42 days of the experiment. All systems were incubated at 20 +/− 1C under a 12 hr light (5400 lux) and dark cycle.

Stock Cultures

Stock cultures were prepared by the same methods to assure that any differences in response would be due to the unique characteristics of the natural source community and not to culture techniques. Stock cultures were acclimated to experimental conditions in 37 L aquaria for not less than two months.

Four stock cultures used in these experiments were started at the same time and were developed from spring plankton communities in Waverly Lake (WL), Freeway Lake (FL), Triangle Lake (TL), and Peavy Arboretum Pond (PA). Predominant genera in lake water used to start the four stock cultures were identified using an inverted microscope and 50 ml settling chambers.

Although all four lakes are mesotrophic they differed in watershed characteristics and production. Waverly Lake and Freeway are the most productive of the four lakes. Waverly Lake is an urban lake and is located in Albany, Oregon. Freeway Lake is located 2 km southeast of Albany in an agricultural drainage basin. Triangle Lake is located in the Coast Range mountains about 45 km west of Eugene, Oregon. The watershed of this lake is predominantly Douglas fir forest. Peavy Arboretum Pond is the least productive of the four lakes and is usually turbid. Peavy Arboretum Pond is located 7 km northeast of Corvallis, Oregon, in an agricultural drainage basin.

Toxicant

Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) was selected because of its widespread use as an herbicide (Eichers *et al.* 1982) and the wealth of available information describing its impact on aquatic systems (Butler *et al.* 1975, Hutber *et al.* 1979, Macek 1976, Torrest and O'Flaherty 1976). Atrazine blocks electron transport in the Hill reaction of photosynthesis (Moreland 1980) which results in reduced primary productivity in aquatic ecosystems (Brockway *et al.* 1984; deNoyelles *et al.* 1982; deNoyelles and Kettle 1985; Stay *et al.* 1985).

Atrazine analysis consisted of extraction from 100 ml water samples with 20 ml of pesticide-quality ethyl acetate followed by concentration of extract and analysis by gas/liquid chromatography (Griffis 1982; Muir and Baker 1976). Average extraction recovery was 104% and was determined using internal spikes. Average precision, determined by duplicate analysis, was 6% relative standard deviations.

Reagent quality atrazine and TD media were used to prepare concentrated stock solutions of atrazine before the start of each experiment. Five replicate microcosms were used for each treatment level and for the control. Treatment concentration of 20, 100, 200, 500, 1,000, and 5,000 µg/L atrazine were selected to match nominal concentrations reported for experiments conducted in experimental ponds (deNoyelles *et al.* 1982; deNoyelles and Kettle 1985).

Because the large volume of sample needed for analysis could not be removed from the microcosm on Day 0, the accuracy of atrazine addition to each treatment was determined at the start of each experiment by adding the appropriate volume of stock atrazine solution to replicate surrogate microcosms made of 1 L TD media and analyzing this water for atrazine concentration. On Day 42, the experiments were terminated and microcosm water was analyzed for atrazine. The average atrazine concentration, 95% confidence intervals, and average percent atrazine remaining on Day 42 of all four experiments are presented in Table 1.

Response Variables

Response variables monitored in these experiments, included dissolved oxygen concentration (DO), pH, redox potential (Eh), heterotrophic activity (HA), net primary productivity (Pn), dark respiration (Rni), and Pn/Rni ratio. Measurements were made on days 1, 2, 3, 5, 7, 10, 14, 21, 28, 35, and 42 after atrazine addition. Before samples were collected or measurements made, mi-

Table 1. Average concentrations (μg/L) and 95% confidence interval (95% CI) of atrazine added on Day 0, and average percent atrazine remaining on Day 42, of all microcosm experiments

Nominal concentration	N	Day 0 Mean	95% CI	Day 42 % Remaining
20	11	17.7	16.1–18.7	76
100	6	99.9	90.6–109.2	69
200	13	204.2	190.3–218.1	71
500	15	491.7	465.7–517.7	76
1000	7	961.4	859.0–1063.8	75
5000	12	4929.2	4742.3–5116.1	80

crocosms were mixed well with a magnetic stir bar, and all measurements and samples were taken 5 cm below the surface at the center of the microcosm.

Measurements of DO, pH, and Eh were made according to USEPA methods (USEPA 1979; USPHS 1980). Precision was determined for each sampling series by making 5 replicate measurements in TD media, near oxygen saturation, without biota at 20°C. Average precision for DO analysis was 6% relative standard deviation. Measurements of redox potential (Eh) were made with a platinum redox electrode. Accuracy of Eh was maintained by calibrating the meter with 192 and 258 mV poised solutions (Orion 1980), and the average precision was 5%. The pH was measured with an Orion Model 801 A ion meter and a Ross electrode. Accuracy was defined with pH 7 and pH 10 buffers and the average precision was 0.23%.

Heterotrophic activity, the fraction of glucose decomposed to CO_2, was measured according to the procedures of Kadota (1972). Uniforming 14-C labeled glucose (0.1 μCi) was added to a 10 ml sample. After four hr incubation at 20°C, the samples were acidified and the CO_2 purged through a CO_2 trap. Activity of the trapped 14-CO_2 was determined by liquid scintillation counting.

Net primary productivity (Pn) and dark respiration (Rni) were estimated by the amount of DO change during the 12 hr light and 12 hr dark periods, respectively, and corrected for the amount of oxygen exchanged with the atmosphere (Stay *et al.* 1985). Net productivity/respiration (Pn/Rni) ratios were calculated, using net productivity and dark respiration.

Statistical Analysis

Data for each variable were analyzed to determine concentrations and times when treatments differed from the controls. Statistical analysis included a folded F test (SAS 1982) to determine homogeneity of replicate variances. When replicate variances of a particular variable were not significantly ($P < 0.05$) different, a linear contrast (t test) with pooled variance was used to determine probability of difference between control and treatment groups. When replicate variances were significantly ($P < 0.05$) different, linear contrasts and degrees of freedom were calculated with a non-pooled variance (SAS 1982).

Results

Predominant genera in the lake communities used to start the four stock cultures and in the microcosms on Day 0 of each experiment are presented in Table 2. Predominant genera in the lake communities used to start the four stock cultures were generally different. Only one genus, *Melosira*, was the predominate member of all four communities. The acclimation procedures used for the stock culture and for the microcosms prior to atrazine addition resulted in four communities which were more similar one to another than the four original lake communities. On Day 0 seven genera; *Scenedesmus*, *Oedogonium*, *Anabaena*, *Hyallella*, *Cyclops*, *Lecane*, and *Philodina* were predominate members of all four microcosm communities. The acclimation procedures also changed the general structure of the plankton community from that of the lakes in which the predominant genera were usually Diatoms to that of the microcosm communities in which predominant genera were usually Green and Blue Green algae.

All response variables were not equally sensitive to the effects of atrazine on the microcosm community. Heterotrophic activity (HA) levels in microcosms exposed to atrazine were usually not significantly ($P < 0.05$) different from the controls and generally the amount of glucose converted to CO_2 was less than 15% of the original amount added. Redox potentials (Eh) were highly variable and no assessments could be made about the effects of atrazine on this response variable. Although DO regimens were sensitive to the effects of atrazine, they are not presented here because they were controlled by primary production and respiration and added little additional information.

Dark respiration (Rni) was relatively insensitive and generally microcosms exposed to less than 500 μg/L were not significantly ($P < 0.05$) different from their controls. Net primary productivity (Figure 1), net productivity/dark respiration ratios (Figure 2), and pH (Figure 3) were the most sensitive response variables to atrazine addition. Generally the responses of the 1,000 and 5,000 μg/L treatments were similar to those of the 500 μg/L treatment and are not shown in the Figures.

Net primary productivity (Pn) values in treatment microcosms developed from WL, FL, and TL and exposed to levels of atrazine of 100 μg/L and greater were significantly ($P < 0.05$) less than those of their respective controls in all measurements made during the first 14 days (Figure 1). These microcosms generally did not recover to control levels for the remainder of the experiment. Pn values in treatment microcosms developed from PA were consistently less than the controls but differences were not significant ($P < 0.05$) at atrazine exposures of less than 200 μg/L.

Table 2. Predominant genera in plankton samples from Waverly Lake (WL), Freeway Lake (FL), Peavy Arboretum (PA), and Triangle Lake (TL), which were used to start stock cultures, are marked with 0. Predominate genera in microcosms on day 0 are marked with an X

	WL	FL	PA	TL		WL	FL	PA	TL
Single-cell Green Algae					**Diatoms**				
Closterium		0	X		*Melosira*	0	0	0	0
Cosmarium	X			0	*Nitzschia*	X	0X	0	
Ankistrodesmus	X	X		X	*Synedra*		0X	0X	
Scenedesmus	X	X	X	X	*Tabellaria*				0
Pediastrum	X	X		X	*Rhopalodia*	X		X	
Dictyosphaerium					*Eunotia*		0		0
Coelastrum		X			*Cymbella*		0X	X	
Crucigenia	X				*Achnanthes*			0	
Nephrocytium			X		*Asterionella*	0			
					Surirella			0	
Filamentous Green Algae					*Fragillaria*			X	
Spirogyra		X	X	X	*Navicula*		0		
Stigeocolonium			X	X					
Cylindrocapsa	X				**Amphipoda**				
Mougeotia			0	X	*Hyalella*	0X	X	X	0X
Oedogonium	X	0X	X	X					
Geminella			X		**Ostracoda**				
Ulothrix				0	*Candona*	0			
Zygnema			X		**Copepoda**				
Blue Green Algae					*Cyclops*	X	X	0X	X
Anacystis				0	*Diaptomas*	0			0
Aphanizomenon	0	X							
Oscillatoria	0X	0X			**Cladocera**				
Phormidium		X	0X		*Alonella*		X		
Tolypothrix	X		X	X	*Moinodaphnia*				0
Anabaena	X	X	X	X	*Bosmina*	0			0
Gomphosphaeria				X	*Chydorus*		X	X	X
Crysococcus		X	X						
					Rotifera				
Flagellated Algae					*Keratella*	0	X	X	
Cryptomonas	X				*Lepadella*		0X		X
Mallomonas		X			*Lecane*	X	X	X	X
Volvox	0				*Monstyla*	X		X	X
Ceratium				0	*Kellicottia*				0
Crysococcus		X	X		*Tricocerca*	0		X	0X
Ochromonas	X			X	*Philodina*	X	X	X	X
Trachelomonas	0								

The magnitude of reduction of Pn in treatments compared to the controls was greater in microcosms developed from WL and FL than in microcosms developed from TL and PA. The pattern of greater response difference from the controls in microcosms derived from WL and FL than in microcosms derived from TL and PA sources was observed with all response variables affected by atrazine.

Net productivity/dark respiration rates (Pn/Rni) in microcosms exposed to 100 μg/L and greater were generally significantly ($P < 0.05$) less than Pn/Rni in their respective controls during the first 14 days (Figure 2). Atrazine concentrations which caused significant reduction in Pn/Rni ratios were more consistent among the four communities than concentrations which caused reductions in Pn. Pn/Rni ratios in treatment microcosms developed from all four communities recovered to their respective control levels by the end of the tests.

The pH values in the four microcosm communities were sensitive indicators of the effects of atrazine (Figure 3). The pH values in all treatment microcosms exposed to 100 μg/L and greater were generally significantly ($P < 0.05$) less than those of their respective controls and generally microcosms exposed to 200 μg/L and greater generally did not recover to control levels during the experiment.

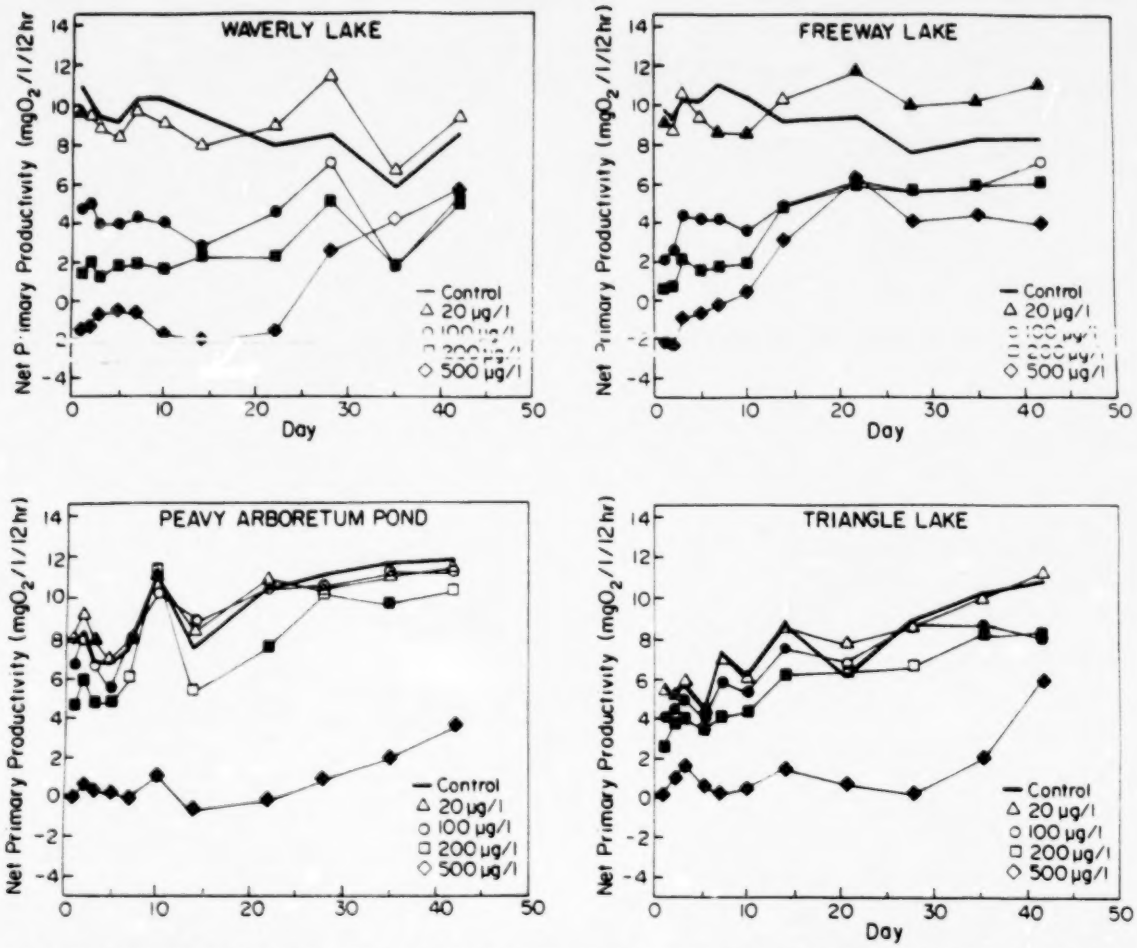

Fig. 1. Mean net primary productivity (Pn) of Leffler microcosms exposed to atrazine. Source communities used to develop these microcosms were from Waverly Lake (WL), Freeway Lake (FL), Peavy Arboretum Pond (PA), and Triangle Lake (TL). Points of significant ($P < 0.05$) linear contrast from control are presented with darkened symbols

Discussion

The response variables proposed by Leffler were selected both to represent major ecosystem components which are most likely to change under stress and to require only simple analytical techniques. Toxicants do not always affect each component equally and therefore response variables are not expected to be equally impacted. Redox potential and pH represent the physical-chemical state of the ecosystem, and decomposition of glucose represents the heterotrophic activity (HA) of the decomposer community. Dissolved oxygen lost during the dark cycle (Rni) is a measure of respiration of all aerobic processes in the ecosystem and DO gained during the light cycle (Pn) represents net productivity of the ecosystem. The Pn/Rni ratio is a measure of the balance between the anabolic and catabolic processes of the system. One index that can be used to describe the responses of the microcosms is the lowest observed ($P < 0.05$) effect level (LOEL) in the variables which illustrates the greatest sensitivity to the toxicant.

In these microecosystems, HA, Eh, and Rni were not as sensitive to atrazine as Pn, Pn/Rni, and pH. Atrazine resulted in a reduction of autotrophic

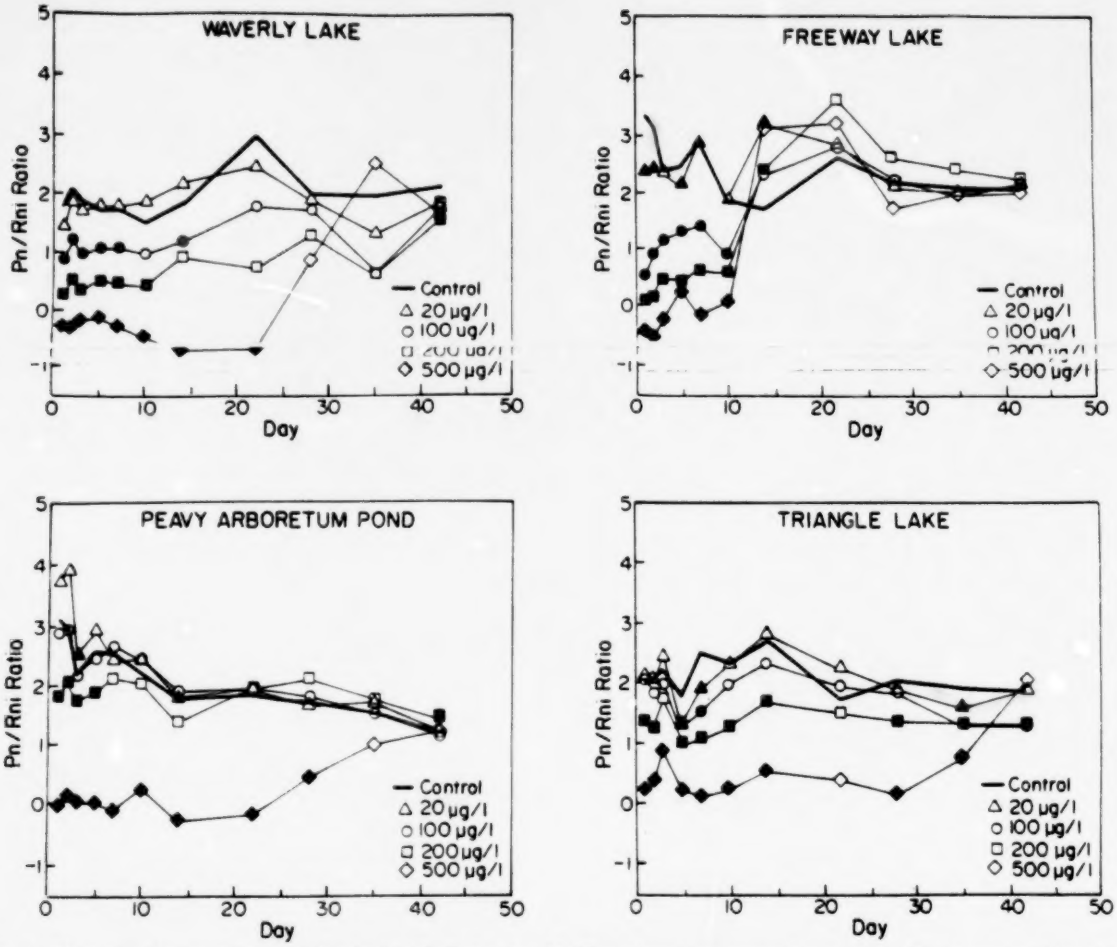

Fig. 2. Mean net primary productivity/respiration (Pn/Rni) ratio of Leffler microcosms exposed to atrazine. Source communities and symbols as in Figure 1

activity in microcosms developed from all four source communities. The lowest observed effect level for Pn in three of the four ecosystems was 100 µg/L. In PA the LOEL was 200 µg/L and treatments exposed to less than 500 µg/L generally recovered to control levels after day 7. Although Pn in treatments of WL, FL, and TL approached controls levels, differences generally were significant, and recovery did not occur during the experiment. The LOEL values with the Pn/Rni ratio were the same as those of Pn, but recovery generally occurred in all treatments before the end of the experiment. The homeostatic property of these microecosystems enabling them to adjust the relative proportions of production and respiration to those of the controls appears independent of whether or not Pn recovered. The physical-chemical response of the four microcosms as measured by pH was similar to that of Pn and is probably an indirect effect of the interaction between primary production and the carbonate buffer system in the microcosms.

A basic assumption in using naturally derived microcosms for screening potentially hazardous chemicals is that the functional equivalence among organisms which are selected by the microcosm acclimation procedure is sufficiently high so that the responses at the ecosystem level of biological organization is independent of the specific organisms in the microcosms. As such, response of naturally derived microcosms should be independent of their

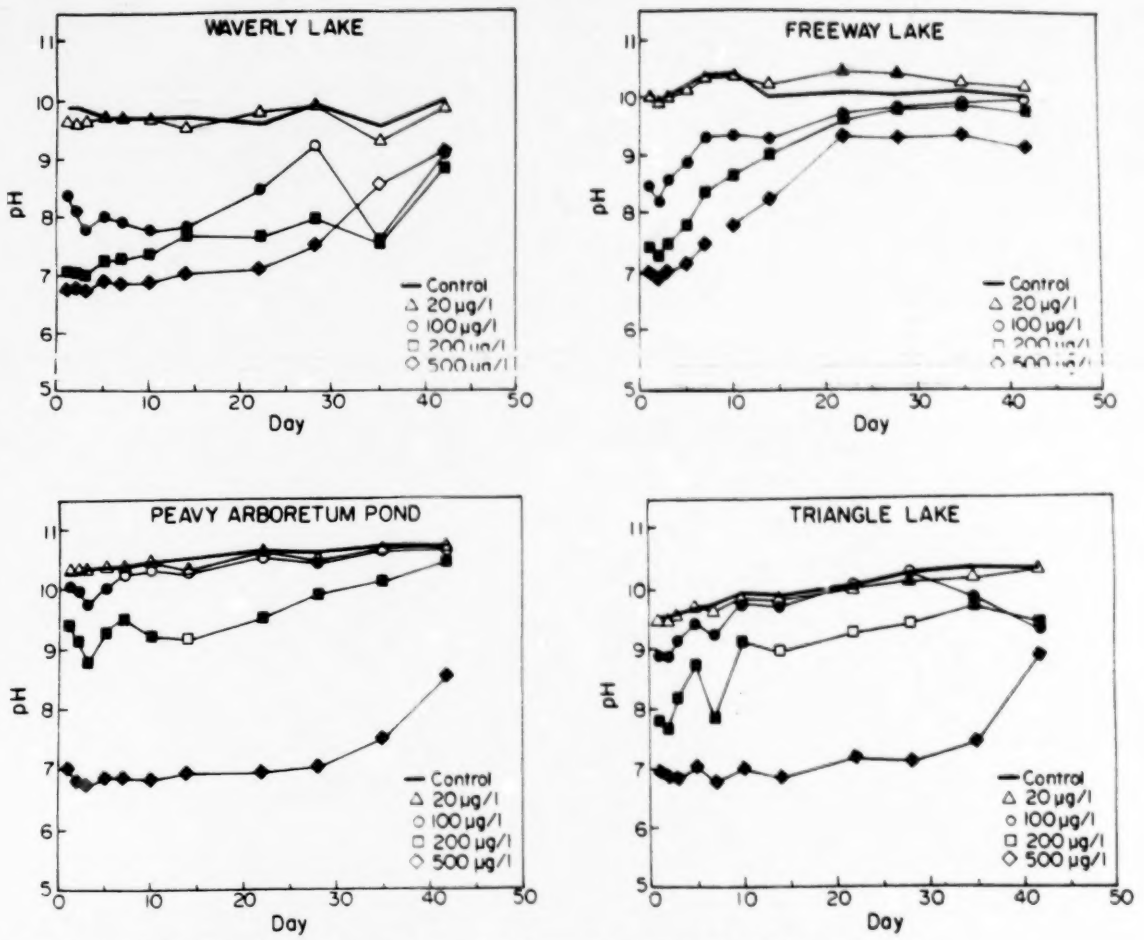

Fig. 3. Mean pH of Leffler microcosms exposed to atrazine. Source communities and symbols as in Figure 1

source communities. One of the objectives of our study was to compare the responses of microcosms developed from four different source communities.

Microcosms developed from the four source communities were only partly successful in producing similar responses at 100 and 200 µg/L atrazine exposures. In all four microcosms Pn, Pn/Rni, and pH were reduced by atrazine; however, the LOEL of the PA community differed from the other three communities. In other experiments conducted by the authors using fluorene as a toxicant (Stay *et al.* 1988), PA was also less sensitive than WL, FL, and TL. Although the results of the comparisons presented here are not conclusive, it appears that it is possible to develop a less sensitive ecosystem. This variation in sensitivity lends support to defining the sensitivity of each source community by its response to a standard set of chemicals as suggested by Leffler (1984).

Another objective of this study was to describe the sensitivity and accuracy of the Leffler test procedure. Accuracy in this sense is a measure of how well the microcosms reflect concentrations of chemicals which cause change or dysfunction in natural ecosystems. Microcosms only recently have been used in toxicity tests and there are no standard tests with which to compare sensitivity of ecosystem level tests. Nor has an acceptable level of sensitivity been defined for ecosystem level measurements. Yount and Shannon (In Press) have evaluated the sensitivity of this microcosm with the fathead minnow (*P. promelas*) bioassay by com-

paring their relative hazard ranking of different toxicants. They found the ranking by both systems to be similar for general narcotics but different for compounds with specific modes of action.

The sensitivity of LOEL values of response variables measured in the experiments presented here were compared with acute (EC50) (Larsen *et al.* 1986) and chronic values (Macek 1976) reported for single species bioassays and to LOEL values of other microcosm studies that used atrazine (Table 3). The range of EC50 values reported for the algal species was 19 μg/L for *C. reinhardi* to 325 μg/L for *C. vulgaris*. Chronic studies, which are a close population level analog of the microcosm studies, ranged between 120 μg/L for *S. fontinalis* to 520 μg/L for *P. promelas*. The LOEL values of 100 and 200 μg/L determined with microcosms developed from the four different water bodies are well within this range of acute and chronic values and suggest that this ecosystem level test is as sensitive and less variable than single species bioassays using several standard test organisms. These comparisons suggest that the use of Leffler microcosms to develop information on modes of action and hazard ranking which in turn can be used to more efficiently select population studies is a valid one.

The Leffler microcosm was also as sensitive to atrazine as the Brockway microcosm (1984), and the Standardized Aquatic Microcosm (SAM) (Stay *et al.* 1985). The Brockway microcosm, like the Leffler microcosm, was derived from natural communities and the SAM was developed from select animal and algal monocultures. In all three microcosm types, autotrophic activity was reduced at exposures greater than 50 μg/L. Determinations of Pn/Rni ratios in the SAM indicated that the LOEL was identical to that of the Leffler microcosms.

In order to evaluate accuracy, responses of the Leffler microcosms were compared to responses reported for experimental ponds (deNoyelles *et al.* 1982; deNoyelles and Kettle 1985) exposed to the same concentrations of atrazine (Table 3). In both systems, primary productivity was significantly reduced immediately following addition of 100 μg/L or more atrazine. Recovery of primary productivity in the ponds occurred at all atrazine exposures within 30 days and was probably due to the development of resistant phytoplankton communities (deNoyelles and Kettle 1985). Pn generally did not recover to control levels in the Leffler microcosms which suggests that resistant plankton communities did not develop.

Although the plankton community in the ponds recovered, the macrophyte-epiphyte community did not. Macrophyte community structure was changed in treatment ponds of 100 μg/L and greater, and macrophytes were unable to sustain growth rates necessary to replace biomass lost to grazing by grass carp at exposure concentrations of 20 μg/L (Carney 1983). The inability of the Leffler microcosms, as well as the macrophyte-epiphyte communities in the ponds, to develop an atrazine resistant community was probably due to the species pool of the microcosms and the long generation time of the pond macrophyte community. These comparisons suggest that attributes, such as species pools and generation times, are relevant when making laboratory to field comparisons.

Although the ecosystem level measurements made in the microcosms could not have predicted the response of the macrophyte community, ecosystem dysfunction in the ponds was accurately predicted. It appears that concentrations of toxicants that cause damage or changes in the functional integrity of these microecosystems can be used to predict concentrations that will cause dysfunction in natural systems. Concentrations below the LOEL in all Leffler microcosms except those developed from PA, probably would not have caused damage or change in the experimental pond ecosystems.

Interpretation of microcosm experiments have accurately reflected ecosystem level changes which could not have been inferred from population studies. Because measurements made at one level of ecological organization cannot easily be used to predict changes at another level, hazard assessment should allow for testing at several levels of biological organization (Cairns 1984). At present, there does not appear to be a generally accepted method for using microcosm or ecosystem level response variables to develop criteria for hazardous compounds. Because there is an absence of hazard assessments at this level of biological organization, and because such assessments provide unique information, additional research should be conducted to develop methods for using ecosystem level assessments along with other more conventional measurements in the development of criteria for hazardous compounds.

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Table 3. The responses of single species bioassays, multispecies assays, and experimental ponds exposed to atrazine are presented for comparison with those of the Leffler microcosm. Acute concentrations (μg/L) are 48 h EC50 values (Larsen *et al.* 1986) and the two values presented for each species are from duplicate bioassays. Chronic concentrations (μg/L) are lowest atrazine concentration resulting in change over extended exposure periods (Macek 1976). LOEL is the lowest exposure concentration (μg/L) causing an observed ($P < 0.05$) effect in microcosms (Brockway *et al.* 1984; Stay *et al.* 1985) and experimental ponds (deNoyelles *et al.* 1982; deNoyelles and Kettle 1985)

Single species assays (μg/L)		Multispecies assays LOEL (μg/L)	Experimental ponds LOEL (μg/L)
Acute	EC50		
		Reduced Autotrophic Activity	Reduced Autotrophic Activity
Chlamydomonas reinhardi	48 19		
		Brockway >50 μg/L Leffler Pn 100 μg/L SAM Pn 100 μg/L	Plankton Pn 100 μg/L
Selenastrum capricornutum	53 54		Macrophytes Without Grass Carp 100 μg/L With Grass Carp 20 μg/L
		Reduced Pn/Rni	
Scenedesmus obliquus	38 57		
		Leffler 100 μg/L SAM 100 μg/L	
Ankistrodesmus sp.	72 61		
		Recovery to Control Levels	Recovery to Control Levels
Ulothrix subconstricta	88		
		Leffler <100 μg/L SAM <500 μg/L	Plankton ≤500 μg/L
Stigeoclonium tenue	127 224		Macrophytes Without Grass Carp <100 μg/L With Grass Carp (None)
Anabaena cylindrica	253 178		
		Development of Resistant Community	Development of Resistant Community
Chlorella vulgaris	305 325		
		Leffler (None) SAM (None)	Plankton ≤500 μg/L Macrophytes (None)
Chronic			
Chironomus tentans	230		
Daphnia magna	250		
Gammarus fasciatus	140		
Pimephales promelas	520		
Salvelinus fontinalis	120		

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